RESEARCH NOTE

ELSEVIER

Postharvest Biology and Technology 25 (2002) 235–239

Postharvest Biology and Technology

www.elsevier.com/locate/postharvbio

Research note

Quality of erect-type blackberry fruit after short intervals of controlled atmosphere storage☆

P. Perkins Veazie *, J.K. Collins

United States Department of Agriculture, Agricultural Research Service, South Central Agricultural Research Laboratory, PO Box 159, Lane, OK 74555, USA

Received 23 March 2001; accepted 9 September 2001

Abstract

'Navaho' and 'Arapaho' blackberries (*Rubus* sp.) were stored at 2 °C in ambient atmosphere (0.03 kPa CO_2, 21 kPa O_2) or CA (15 kPa CO_2, 10 kPa O_2) with the following treatments: 3 days of CA storage plus 11 days in air; 7 days of CA storage plus 7 days with air; 14 days of constant CA storage. Titratable acidity was higher after 3 and 14 days CA storage for 'Arapaho' and 'Navaho', respectively, compared with control fruit. At least 7 days of CA was needed to reduce incidence of decayed fruit in both cultivars. Monomeric anthocyanin content decreased 20% after 7 days CA storage compared with control blackberries for both cultivars. Consumer panels did not detect off-flavors in blackberries treated with CA for 3 or 7 days. Published by Elsevier Science B.V.

Keywords: Anthocyanins; Controlled atmosphere; Quality; *Rubus*; Shelf life; Storage

1. Introduction

'Navaho' and 'Arapaho' blackberries are thornless erect-type cultivars with firm berries and a shelflife of 7 days when cooled immediately after harvest and stored at 2 °C at 90–95% relative humidity (RH). Decay is the primary limiting factor in longer storage (> 7 days) of these fruit (Perkins-Veazie et al., 1999). Robinson et al. (1975) found that 15 kPa CO_2 and 5–10 kPa O_2 controlled decay in 'Bedford Giant' blackberries, but no effects of CO_2 on soluble solids content, titratable acidity, anthocyanins or flavor were reported. 'Cherokee' blackberries harvested for processing were held under short storage durations at high storage temperatures (2 days at 29–36 °C)

☆ Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the US Department of Agriculture. All programs and services of the US Department of Agriculture are offered on a nondiscriminatory basis without regard to race, color, national origin, religion, sex, age, marital status, or handicap. The article cited was prepared by a USDA employee as part of his/her official duties. Copyright protection under US copyright law is not available for such works. Accordingly, there is no copyright to transfer. The fact that the private publication in which the article appears is itself copyrighted does not affect the material of the US Government, which can be freely reproduced by the public.

* Corresponding author. Tel.: + 1-580-889-7395; fax: + 1-580-889-5783.

E-mail address: pperkins-usda@lane-ag.org (P. Perkins Veazie).

0925-5214/02/$ - see front matter. Published by Elsevier Science B.V.
PII: S0925-5214(02)00025-X

under 40 kPa CO_2 (Morris et al., 1981). After storage, these fruit had 20% less decay than control fruit with no deleterious changes in soluble solids, titratable acidity or anthocyanins, but fruit were rated unacceptable by taste panelists due to off-flavor development. The purpose of this study was to determine the quality and flavor of blackberries after short interval CA treatment.

2. Materials and methods

Fully firm black fruit of 'Navaho' and 'Arapaho' were harvested twice in 1998 and 1999 in established blackberry plots at Lane, OK. No pre- or post-harvest fungicides were applied. Fruit were pre-cooled for 14 h at 2 °C and 95% RH. Four replicates, consisting of 200 ± 30 g fruit per treatment, were placed in 0.9 l canning jars, with lids adapted for inlet and outlet gas flow lines to humidified atmospheres (95% RH) of control (21 kPa O_2, 0.03 kPa CO_2) or CA (10 kPa O_2, 15 kPa CO_2) were obtained by connecting lines from a commercial grade CO_2 tank, (regulated with capillary tubes) to flow boards and manifolds connected to jars (Claypool and Keefer, 1942). Flow rates were maintained at 70 ml min^{-1} per jar and atmospheres monitored daily. One milliliter gas samples were analyzed every 3 days for CO_2 and O_2 concentrations using a gas chromatograph (Shimadzu 14A, Columbia, MD) equipped with a thermal conductivity detector and a CTR-I column [$3.1 \times 0.003/0.006$ m (Alltech Assoc., Deerfield, IL)]. Treatments for the study were as follows: 3 days of CA storage plus 11 days in air; 7 days of CA storage plus 7 days in air; 14 days of constant CA storage. Fruit in control jars were held for 14 days under humidified air. All fruit were held at 2 °C during and after CA treatment.

Fruit weight loss was assessed after 14 days of storage and berries were subjectively rated for incidence of decay, leakiness, and softness (Perkins-Veazie et al., 1996). For compositional analysis, 40 g berries free of decay per treatment replicate were pureed and duplicates were analyzed for percent titratable acidity (TA) and percent soluble solids concentration (SSC), as described in Perkins-Veazie et al. (1996). Monomeric (cyanidin-3-glucoside, MW 449.2, extinction coefficient 26 900) and polymeric anthocyanin content were determined by pH differential and bisulfite bleaching methods (Rommel et al., 1992).

'Navaho' and 'Arapaho' berries were evaluated for flavor and taste acceptability after 3 and 7 days of CA storage only, to eliminate the possibility of consuming fruit with slight decay. Subsamples consisting of three jars per cultivar and treatment were used to provide fruit for taste tests. Fifteen to 20 consumer panelists evaluated berries for odor, texture, sweetness, flavor, tartness, bitterness and overall acceptability using a 1 (poor) to 9 (excellent) hedonic scale. Two to three berries per variety and treatment were used for each sample. 'Navaho' was used in 1998 and 1999 and 'Arapaho' in 1999 (two harvest dates per year).

The experiment was conducted as a split plot design, with variety as main plot and treatment and storage interval as sub plots. The experiment was duplicated over years, using two harvest dates per year (early and midseason), with the exception of taste tests. Data were analyzed using Analysis of Variance (ANOVA). Interactions for cultivar and treatment and days of storage and treatment were significant, therefore significance between paired means for treatments was determined using Student's t-test, and differences among storage days within a treatment and cultivar were determined using LSD (SAS, v. 7.0, Cary, NC). ANOVA was used to analyze taste test data, with no significant interactions found among treatments, days storage, year, and/or cultivar.

3. Results and discussion

Weight loss was minimal in this study and averaged 0.7–1.2% over 14 days storage with no significant treatment differences (data not shown). Air-stored (control) 'Navaho' fruit, averaged over treatment intervals, had less leaky or decayed berries compared with 'Arapaho' (Table 1), as reported in other storage studies (Perkins-Veazie et al., 1999). Seven days application of CA effectively reduced decay in both 'Arapaho' and 'Navaho', compared with control blackberries. Seven and 14 days CA treatment effectively decreased the incidence of leaky berries and increased the number of marketable berries for 'Arapaho', compared with control fruit. Treatment had no effect on the incidence of soft berries in either cultivar (mean of 14 and 15% for 'Arapaho' and 'Navaho', respectively).

Compared with fruit at harvest, all stored blackberries had lower titratable acidity and higher pH values, but the degree of change depended on cultivar and treatment (Table 2). 'Navaho' berries were lower in pH, higher in TA, SSC, and anthocyanin content than 'Arapaho', consistent with other 'Navaho'–'Arapaho' comparisons (Perkins-Veazie et al., 1999). In 'Arapaho' berries, TA was consistently higher and pH lower in CA fruit after all storage intervals compared with control fruit, while CA-treated 'Navaho' berries changed significantly only after 14 days storage, relative to controls. Morris et al. (1981) reported no changes in soluble solids, titratable acidity or anthocyanins with 'Cherokee' blackberries stored for 2 days in 40 kPa CO_2 at 29–36 °C compared with air stored fruit.

Total monomeric anthocyanin content was reduced by 20% after 7 days CA storage in 'Arapaho' or 'Navaho' blackberries, compared with fruit from control treatments (Table 2). These fruit were held without CA for an additional 7 days and still had less anthocyanin than fresh or control fruit, indicating an irreversible loss of pigment. Polymeric browning, an indication of anthocyanin degradation, was $<10\%$ for all treatments (data not shown). To our knowledge, this is the first report of CA storage reducing anthocyanin content in blackberry. In 'Arapaho' and 'Navaho' blackberries, 85–87% of the anthocyanin pigment is cyanidin-3-glucoside (Fan-Chiang, 1999), and is reported to be the most unstable of the anthocyanin pigments due to its high reactivity (Mazza and Miniati, 1993).

Holcroft and Kader (1999) found a 16–20% loss in anthocyanin content in strawberries after treatment with 20 kPa CO_2 and storage at 5 °C. These strawberries had a higher pH and lower TA compared with air-stored fruit, unlike the blackberries in our study. The similar reduction in anthocyanins in blackberries and strawberries

Table 1
Selected attributes of 'Arapaho' and 'Navaho' blackberries held in controlled atmosphere (CA) (15 kPa CO_2, 10 kPa O_2) or air (control) at 2 °C with 95% RH for up to 14 days

Cultivar	Days of treatment	Decayed berries (%)		Leaky berries (%)		Marketable berries[a] (%)	
		Control	CA	Control	CA	Control	CA
Arapaho	3	25	16*	30	26	77	82
	7	31	14*	31	17*	75	87*
	14	33	9*	50	9*	67	89*
	Mean	30	13	37	18	73	86
	LSD[b]	9	5	10	7	6	4
Navaho	3	16	11	18	18	85	83
	7	15	11*	19	27	85	84
	14	20	5*	39	10*	73	90*
	Mean	17	9	25	18	81	86
	LSD	7	6	17	13	9	8

[a] Marketable berries represent 100% − [sum (decayed + leaky + soft berries)/3].

[b] Means separated by LSD within cultivar and treatment, $P \leq 0.05$. Means separated between treatments within cultivar by Students' t-test ($P \leq 0.05$), with significant differences indicated by *. Interactions of storage × cultivar and treatment × storage × cultivar significant, $P \leq 0.05$.

Table 2
Compositional changes of 'Arapaho' and 'Navaho' blackberries held in CA storage at 2 °C up to 14 days

Cultivar	Days of treatment	Soluble solids concentration (%)[a]		Titratable acidity (%)		pH		Total monomeric anthocyanin (mg per 100 g)	
		Control	CA	Control	CA	Control	CA	Control	CO_2
Arapaho	0	8.7		0.82		3.37		122.1	
	3	8.4	8.2	0.67	0.75*	3.75	3.67*	116.4	122.1
	7	8.1	7.9	0.63	0.76*	3.75	3.64*	123.4	99.13*
	14	8.0	8.5*	0.65	0.71*	3.78	3.68*	123.6	93.6*
	Mean	8.3	8.4	0.70	0.77	3.64	3.57	121.6	113.5
	LSD	0.8	0.9	0.15	0.14	0.25	0.20	3.1	5.3
Navaho	0	12.1		1.0		3.32		107.7	
	3	11.4	11.6	0.88	0.84	3.62	3.65	131.7	128.6
	7	11.6	12.3*	0.84	0.86	3.62	3.64	145.3	113.6*
	14	11.1	11.4	0.80	0.97*	3.67	3.49*	125.1	100.9*
	Mean	10.7	11.7	0.89	0.92	3.48	3.42	120.8	111.0
	LSD	0.4	0.4	0.10	0.09	0.12	0.12	2.4	3.0

Fruit were stored in air (control) or CA (15 kPa CO_2, 10 kPa O_2) at 2 °C with 95% RH.

[a] Means separated by LSD within cultivar and treatment, $P \leq 0.05$, and between treatments within cultivar by Students' t-test ($P \leq 0.05$), with significant differences indicated by *. Interactions of storage × cultivar and treatment × storage × cultivar significant, $P \leq 0.05$.

after treatment with 15–20 kPa CO_2, despite opposite effects on pH and TA, indicate that an enzymatic process is involved, rather than a copigmentation effect with organic acids or other flavanoids. Rommel et al. (1992) found that anthocyanin (cyanidin-3-glucoside) was less degraded in juice of 'Thornless Evergreen' blackberries when given a combination of high temperature and short time pasteurization, and speculated that pigment degradation was due to glycosidases or polyphenoloxidase.

Sensory taste panelists were unable to discern differences in odor or flavor between CA treated and control fruit (data not presented). No differences among years were found for 'Navaho'. 'Navaho' and 'Arapaho' fruit were similar in 1999 in all categories except texture (4.4 (softer) and 5.1 for 'Arapaho' and 'Navaho', respectively). All fruit were rated around six for overall acceptability, indicating fruit had acceptable quality after 7 days of storage regardless of treatment. The lower pH and higher TA of CA-stored fruit did not adversely affect tartness or overall flavor characteristics. CO_2 levels in our study never exceeded 15 kPa and O_2 levels were maintained at 10 kPa, preventing blackberries from becoming anaerobic.

4. Conclusion

Both 'Navaho' and 'Arapaho' blackberries had less decay when stored for 7 days at 15 kPa CO_2 and 10 kPa O_2, with no adverse affects on flavor, compared with fruit stored in ambient atmosphere. However, after 7 days of CA treatment, there was a significant loss in anthocyanin content.

Acknowledgements

The authors thank Sheila Magby and Bobbie Ceriotti for their technical assistance.

References

Claypool, L.L., Keefer, R.M., 1942. A colorimetric method for CO_2 determination in respiration studies. Proc. Am. Soc. Hort. Sci. 40, 177–186.

Fan-Chiang, H., 1999. Anthocyanin pigment, nonvolatile acid and sugar composition of blackberries. MS Thesis, Oregon State University.

Holcroft, D.M., Kader, A.A., 1999. Controlled atmosphere-induced changes in pH and organic acid metabolism may affect color of stored strawberry fruit. Postharvest Biol. Technol. 17, 19–32.

Mazza, G., Miniati, E., 1993. Anthocyanins in Fruits, Vegetables and Grains. CRC Press, Boca Raton, pp. 85–130.

Morris, J.R., Spayd, S.E., Brooks, J.G., Cawthon, D.L., 1981. Influence of postharvest holding on raw and processed quality of machine-harvested blackberries. J. Am. Soc. Hort. Sci. 106, 769–775.

Perkins-Veazie, P., Collins, J.K., Clark, J.R., 1996. Cultivar and maturity affect postharvest quality of fruit from erect blackberries. HortScience 31, 258–261.

Perkins-Veazie, P., Collins, J.K., Clark, J.R., 1999. Interaction of cultivar and storage temperature on the shelflife of blackberry fruit. Fruit Var. J. 534, 201–208.

Robinson, J.E., Browne, K.M, Burton, W.G., 1975. Storage characteristics of some vegetables and soft fruits. Ann. Appl. Biol. 81, 399–408.

Rommel, A., Wrolstad, R.E., Heatherbell, D.A., 1992. Blackberry juice and wine: processing and storage effects on anthocyanin composition, color and appearance, J. Food Sci. 57:385–391, 410.